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The effectiveness of an electric "wash toothbrush" on oral plaque control – A pilot study

Introduction: Mechanical plaque control by means of self-responsible, home-based oral hygiene is essential for the prevention of caries and periodontal diseases. In this respect, many elderly patients are at increased risk. It has already been shown that an electric toothbrush with oscillating-rotating movement and a continuous water supply has a positive effect on dental plaque control when compared to a manual toothbrush. The aim of the present pilot study was to evaluate if sonic toothbrushes likewise benefit from a continuous water supply during the brushing process and if they have a positive effect on dental plaque control in younger seniors.

Methods: The study included 12 subjects (mean age 72.08 ± 3.88 years, 6 females, 6 males). Following a plaque accumulation phase of 48 hours, an electric toothbrush with oscillating-rotating movement and a sonic toothbrush with (wash toothbrush) and without continuous water supply were tested in a single application. The Quigley-Hein-Index (QHI) and the Approximal-Plaque-Index (API) were each determined before and after brushing to assess plaque reduction.

Results: The electric toothbrush with an oscillating-rotating movement pattern with continuous water supply (WORT) showed a higher reduction of the plaque index readings compared to the electric toothbrush with oscillating-rotating movement pattern without water supply (ORT) in the area of the smooth surfaces (WORT: Δ QHI 1.68 ± 0.28; ORT: Δ QHI 1.41 ± 0.34) and approximal surfaces (Δ API WORT: 20.43 ± 18.7 %; Δ API ORT: 19.85 ± 18.03 %). These results, however, were not statistically significant. The sonic toothbrush with continuous water supply (WST) showed a significantly higher reduction of plaque index compared to the sonic toothbrush without water supply (ST) on the smooth surfaces (WST: Δ QHI 1.88 ± 0.33, ST: Δ QHI 1.27 ± 0.25, $p < 0.001$) and approximal surfaces (Δ API WST: 30.14 ± 14.85 %, Δ API ST: 14.12 ± 10.6 %, $p = 0.006$). A higher reduction of the plaque index value was determined on both the smooth and approximal surfaces using the WST as compared to the WORT, although the results were not statistically significant.

Conclusion: An electric toothbrush with a continuous water supply has a positive effect on dental plaque control in elderly subjects. Sonic toothbrushes benefit from a continuous water supply to a greater extent than electric toothbrushes with an oscillating-rotating movement pattern. Further investigations should evaluate if the use of an electric toothbrush increases the "hydrodynamic effect", thereby facilitating that difficult-to-clean niches such as exposed root surfaces or crown margins are reached.

Keywords: oscillating-electric toothbrush; sonic toothbrush; continuous water supply; plaque control

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1. Introduction

Mechanical plaque control and biofilm removal play a critical role in the prevention of caries, gingivitis and periodontitis [2]. The removal of the biofilm is not just the responsibility of the dentist, but rather, primarily that of the patient who should be self-responsible for undertaking home-based oral hygiene measures on a regular basis [5]. Due to the fact that caries and inflammatory periodontal diseases continue to be "common diseases", it appears that the quality of home-based plaque removal in large parts of the population is inadequate. Especially older patients display a higher plaque affliction compared to younger ones [16]. In the Fifth German Oral Health Study (DMS V), 28 % of the examined senior citizens had at least one root surface caries or root surface filling. With respect to the dentulous study participants, this was as high as 32 % [11]. For this reason, they should be counted as patients at risk for root surface and crown marginal caries [11]. The cause for increased root and crown margin caries susceptibility in older patients is multifactorial. As an example, exposed root surfaces or exposed restoration margins due to periodontal problems foster plaque retention and caries predilection sites [3].

As part of gingivitis and caries prophylaxis, it is not only necessary that smooth surfaces are cleaned, but also interdental spaces, especially given that tooth surfaces below the approximal contacts represent predilection sites for caries and gingivitis [19]. In spite of this, these areas are often not sufficiently reached when simply using a hand and/or an electric toothbrush [24]. If biofilm or food particles cannot be removed with a toothbrush alone, additional hygiene tools such as dental floss or interdental brushes are recommended [7, 23]. However, user acceptance of these additional hygiene tools is to date still considered to be low [11, 31].

Studies in behavioral science have shown that it is difficult to achieve health-related behavioral changes in adults [1]. Thus, patients often overlook dentists' recommendations related to making changes in their oral hygiene habits; such changes may include brushing technique and brushing system, or the additional use of hygiene tools for approximal space cleaning. Moreover, in older patients, a decrease of acuity and motor dexterity (limitations in gross and fine motor skills, decreased vision, decreased cognitive performance) [21] occurs with age; many of them are unable to use conventional toothbrushes to brush their teeth or employ hygiene tools to clean approximal spaces.

In order to assertively improve cleaning performance independent of individual factors such as dexterity, motivation and brushing time, new and more effective toothbrushes are continuously being developed and worked upon. Especially due to the low acceptance of hygiene tools for interdental cleaning, toothbrushes with increased efficiency in this area are desirable. In a survey using a representative sample of the population in the Federal Republic of Germany, it was found that 53 % of respondents used a manual toothbrush and 38 % used an electric toothbrush in the context of home-based oral hygiene [31]. The most common electric toothbrushes have an oscillating-rotating movement pattern or are activated by sound or ultrasound based on the manufacturer's specifications. In literature, oscillating-rotating brushes receive an advantage as a high level of evidence exists with regards to the effectiveness of these brushes [29, 30]. The bristles of sound-activated toothbrushes work mainly using "side-to-side movements" [12]. Cleaning occurs mechanically through the moving filaments themselves, on the one hand, while on the other, vibrations of the toothpaste-saliva mixture in the mouth generate turbulence (hydrodynamic effect). Due to the generated turbulence, the mixture should reach areas which are inaccessible to the toothbrush. In the case of ultrasonic toothbrushes, an additional cavitation effect occurs, thus leading to the removal of the biofilm and the attached plaque [12].

So-called "wash brushes" have been used for many years in households and in industry. These brushes are connected to a high-pressure cleaner or a normal water duct and are thus equipped with a continuous water supply. They are recommended by various manufacturers for their effective as well as gentle cleaning of smooth and sensitive surfaces.

In a pilot study in which the effectiveness of a manual and electric toothbrush was tested with ("wash toothbrush") and without continuous water supply, it could already be shown that an electric toothbrush, equipped with a continuous water supply and having an oscillating-rotating movement pattern, has a positive effect on dental plaque control in both younger and older subjects compared to a manual toothbrush [9]. The aim of this pilot study was to evaluate whether sonic toothbrushes benefit from a continuous water supply during the brushing process and if this has a positive effect on dental plaque control in younger elderly people.

2. Methods

2.1 Study design

The present study is a prospective, single-blind pilot study with crossover design. The study has received a positive vote from the Ethics Committee of the Hannover Medical School (Vote No. 1615–2012).

2.2 Subjects

In the current pilot study, a total of 12 subjects participated voluntarily with their prior written consent, which could thereafter be revoked at any time without giving reasons. The participants were between the ages of 66 and 79 years (72.08 ± 3.88 years); 6 subjects were male and 6 were female. Moreover, the participants were patients receiving a systematic periodontal therapy and part of the recall system at the Clinic for Conservative Dentistry, Periodontology and Preventive Dentistry of the Hannover Medical School. All subjects presented a history of periodontitis, but were periodontally healthy/rehabilitated.

Exclusion criteria included removable dentures, fewer than 20 teeth, PSI code > 2, taking anti-

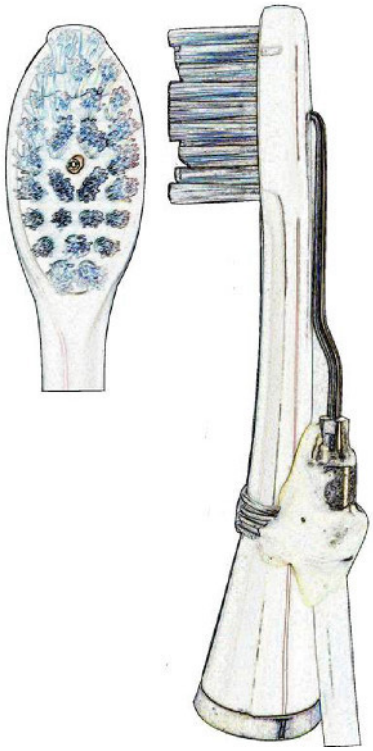


Figure 1 Brush head of the sonic toothbrush with continuous water supply – "washsonic-toothbrush" (WST)

inflammatory or anti-bacterial drugs, systemic disorders that influence oral findings, an age less than 65 years, and motor or sensory limitations.

2.3 Toothbrushes used

Each participant received a conventional electric toothbrush (Oral-B Professional Care Triumph 5000 with an attached Oral-B Precision Clean brush, Procter & Gamble), which had an oscillating-rotating movement pattern (ORT) as well as a sonic toothbrush (ST) (Hydrosonic CHS 100 with the brush head Hydrosonic sensitive (CHS 200), set at 32,000 movements per minute at "intensive" level, Curaprox). Additionally, each subject received a modified electric toothbrush with oscillating movement pattern (WORT) and a modified sonic toothbrush (WST). For this purpose, the conventional toothbrushes described above were modified and equipped with a continuous water supply (Fig. 1 and 2). The water supply was centrally located on the bristle field and was generated by a conventional irrigator (MD 5613 AEG) with a water flow rate of 65 ml per minute. In contrast to a conventional oral irrigator, the supplied water does not exactly strike the tooth surface, nor any existing pockets, but rather is distributed across the bristle field. In this manner, the supplied water is not used for mechanical biofilm disruption, but rather to support the cleaning action of the bristles. Hereafter, the term "wash toothbrush" is used to generally denote a modified toothbrush with continuous water supply.

2.4 Collected parameters

As part of an initial examination (baseline), a general medical history as well as the following parameters were collected:

- General dental examination (01 and resulting DMF-T/-S)
- Periodontal Screening Index (PSI) [15]
- Papilla Bleeding Index (PBI) [20]
- Approximal-Plaque-Index (API) [13]
- Modified Quigley-Hein-Plaque-Index (QHI) [27]

In order to create uniform starting conditions, all subjects received a professional tooth cleaning following the baseline examination. Both groups tested the 4 different toothbrushes in a single application. As part of the baseline investigation, all participants received thorough clarification and instructions by means of models and videos with regard to how to employ the various toothbrushes. The use of each toothbrush was preceded by a 2-day plaque accumulation phase (no home-based oral hygiene, no use of oral hygiene products or dental care products such as candies or chewing gum containing menthol). After testing each toothbrush, a 2-day "wash-out phase" was followed, during which the subjects performed home-based oral hygiene with their usual oral hygiene tools. After this phase, the next 2-day plaque accumulation phase began before testing the next toothbrush.

After the 2-day accumulation phase, the QHI and API indices were used to quantify plaque following staining with a plaque disclosing solution (Mira-2 tone, Hager & Werken). Then, the subjects received different toothbrushes in each of the 4 phases in the following order: an electric toothbrush without and with continuous water supply (ORT and WORT) and a sonic toothbrush without and with continuous water supply (ST and WST). After brushing with each respective toothbrush using medium abrasiveness toothpaste (Elmex Sensitive Professional Repair & Prevent, CP-GABA GmbH), residual plaque was visualized again using plaque disclosing solution and quantified using the QHI and API indices.

All parameters were collected by the same examiner after initial calibration took place together with the project manager. The examiner was unaware that a pre-determined sequence existed, and thus, did not know which toothbrush was being used.

In order to evaluate cleaning effectiveness, the differences of the QHI and API before and after brushing were calculated (below Δ QHI and Δ API). The collection of the plaque indices took place with the help of magnifying loupes (2-fold magnification). A questionnaire was used as part of the initial examination in order to record the oral hygiene habits of the subjects. After the last appointment, the subjects completed a further questionnaire with the purpose of documenting their subjective impression of the tested toothbrushes.

2.5 Statistical analysis

The statistical software program SPSS Statistics 21 for Windows was used to analyze data. First, mean values, standard deviations and frequencies were calculated as part of the descriptive statistics. Subsequently, the calculated mean values were tested for normal distribution using the Kolmogorow-Smirnow test (KS test). Since the tested variables (QHI, API values) were > 0.05, a normal distribution could be assumed. Therefore, a parametric paired t-test was employed to analyze variance for repeated measures within a group (electric toothbrush with oscillating-rotating movement pattern without and with continuous water supply, sonic

	QHI before	QHI after	QHI Difference	API before (%)	API after (%)	API Difference (%)
ST	2.31 ± 0.47	1.04 ± 0.38	1.27 ± 0.25	99.04 ± 3.33 *	84.92 ± 12.59	14.12 ± 10.6 *
WST	2.54 ± 0.4	0.66 ± 0.27	1.88 ± 0.33	98.72 ± 4.44	68.58 ± 14.85	30.14 ± 14.85
ORT	2.29 ± 0.20	0.88 ± 0.37	1.41 ± 0.34	97.88 ± 3.93	78.03 ± 18.5	19.85 ± 18.03
WORT	2.44 ± 0.22	0.76 ± 0.33	1.68 ± 0.28	99.04 ± 2.78	78.61 ± 19.43	20.43 ± 18.7

Table 1 QHI and API of the participants before and after toothbrushing with ST, WST, ORT and WORT, as well as QHI and API differences (* statistically significant)

toothbrush without and with continuous water supply). The means between the tested toothbrushes were compared with the unpaired t-test. The statistical significance level was set at p = 0.05.

3. Results

3.1 Results from baseline examination

No participants in the project had a need for periodontal treatment and all were caries free. The participants had a mean PBI of 0.7 ± 0.3 and a mean DMF-T of 17.8 ± 4.7 (DMF-S: 61.3 ± 23.4). The plaque index value in the area of smooth surfaces (QHI) was on average 1.4 ± 0.3 and 91.5 ± 8.7% in the approximal area (API).

3.2 Comparison of plaque index value reduction between ORT and WORT

With the WORT, the plaque index value on the smooth surfaces (Δ QHI) was reduced on average by 1.68 ± 0.28 and by 20.43 ± 18.7 % in the approximal region (Δ API). With the ORT, on average, a reduction of the plaque index value (Δ QHI) by 1.41 ± 0.34 was achieved on the smooth surfaces and 19.85 ± 18.03 % in the approximal areas. Comparison of the means between WORT and ORT showed a tendency towards a higher reduction of the plaque index value in the area of the smooth surfaces for the WORT, but this was not statistically significant (p = 0.062). There were only slight differences between the two toothbrushes in the area of the approximal surfaces (Table 1).

3.3 Comparison of plaque index value reduction between ST and WST

The WST showed a significantly higher reduction of the plaque index value on the smooth surfaces (p < 0,001) and in approximal areas (p = 0,006) compared to the ST. With the ST, the plaque index value (Δ QHI) was reduced by 1.27 ± 0.25 on the smooth surfaces and by 14.12 ± 10.6 % in approximal areas. With the WST, on average, a reduction of the plaque index value (Δ QHI) by 1.88 ± 0.33 was achieved on the smooth surfaces and 30.14 ± 14.85 % in approximal areas (Table 1).

3.4 Comparison of the reduction in the plaque index values between ST and ORT

With the ORT, the subjects tended to achieve a higher reduction of the plaque index value on the smooth surfaces as well as in the approximal areas than with the ST, but this was not statistically significant (Table 1).

3.5 Comparison of the reduction in plaque index values between WST and WORT

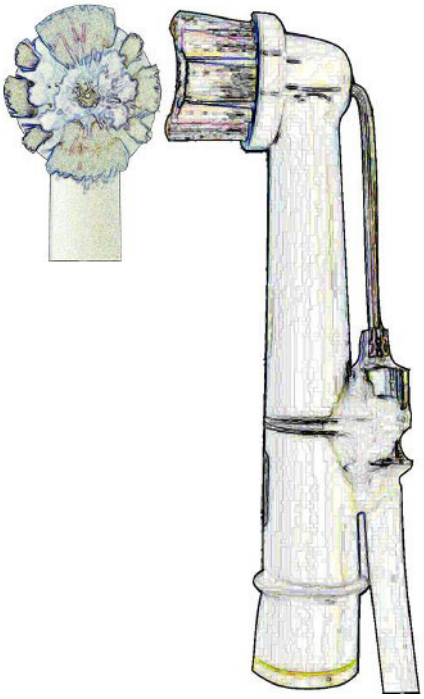
The subjects tended to achieve a higher reduction of the plaque index value with the WST than with the WORT, both on the smooth surfaces and in the approximal areas, but this was not statistically significant (Table 1).

3.6 Evaluation of the questionnaire

75 % of the participants already used an electric toothbrush as part of their home-based oral hygiene. All project participants stated that they had a better "feeling in the mouth" after using the "wash toothbrushes" (WORT, WST) compared with the conventional electric toothbrushes (ORT, ST). Moreover, 83.3 % and 16.7 % preferred the WST and WORT, respectively.

4. Discussion

In the present study, it was observed that there was a tendency towards a higher reduction of the plaque index value on both smooth and approximal surfaces for the electric toothbrush with an oscillating-rotating movement pattern (ORT) compared to the sonic toothbrush (ST). In literature, the efficiency between sonic toothbrushes and electric toothbrushes with oscillating-rotating movement pattern is controversially debated. Some studies affirm that electric toothbrushes with oscillational rotating patterns of movement have a higher plaque and gingivitis reduction as compared to sonic toothbrushes [4, 8]. Other studies, however, observe the opposite [17, 25]. Clinical studies should take into account that home-based oral hygiene may also be incorrectly or inadequately exercised. Ganss et al. (2018) used videos to observe subjects during brushing with an electric as well as a manual toothbrush [6]. For both toothbrushes, identical movement patterns (horizontal and circular brushing movements) were registered. Only 50.5 % of subjects allowed for "passive movements" using the electric toothbrush (positioning the brush head on the tooth with less than 2 movements). This



(Fig. 1 and 2, Table 1: K. Meyer-Wübbold, H. Günay)

Figure 2 Brush head of the electric toothbrush with continuous water supply – "washelectric-toothbrush" (WORT)

"passive brushing" took up less than 10 % of the total brushing time [6]. In spite of this, in order to achieve an optimal brushing performance with electric toothbrushes, "passive movement" makes sense. In order to achieve an optimal brushing result, the brush head should be guided both along the gingival margin as well as along the contour of the tooth and into the interdental space using a small pivoting movement. Also with the sonic toothbrush employed in the present study, the manufacturer recommends an angulation of 45° to the tooth surface for optimal cleaning in the area of the gingival margin. In doing this, the bristles should be placed only lightly without pressure on the tooth surface. For each tooth, the user should stay for 2 to 3 seconds and then slowly perform tilting movements without pressure [Source: instruction manual and instruction video Hydrosonic, Curaprox]. The patients in the present study were indeed intensively instructed at the beginning with regard to the use of the respective toothbrush with the aid of models and videos. However, it cannot be ruled out whether or not the technique specified by the manufacturer was or was not fully implemented. The technique specified by the manufacturer is very similar to the "bass technique" and was therefore difficult for the project participants to implement. In addition, it could be observed that the manufacturer's recommendation of a short, motionless pause of the brush head on the tooth was also difficult for the participants to implement. The subjects quickly became impatient, which was possibly related to the feeling of "being under surveillance". During the use of the ST, the participants repeatedly came back to the movement pattern of a manual toothbrush. Moreover, the subjects were probably not used to perform brushing with minimal pressure. Also, since the sonic toothbrush used in the present study did not have a pressure control, it cannot be ruled out whether or not too much pressure was exerted by the patients; this could possibly have reduced the cleaning performance of the sonic toothbrush.

In the present study, for the modified sonic toothbrush with continuous water supply (WST), a higher reduction in the plaque index was observed compared to all other toothbrushes tested, both on smooth and in approximal surfaces. For sonic toothbrushes, the bristles of the brush head are moved with rapid oscillations, thereby achieving a "hydrodynamic effect". This means that the bristles do not only mechanically clean, but also generate turbulence through vibrations, thus allowing the toothpaste-saliva mixture to remove plaque and bacteria in poorly accessible areas. This effect has been demonstrated in some studies [22]. In the present study, however, the lowest reduction of the plaque index value was observed on smooth and in approximal surfaces for the sonic brush without continuous water supply (ST). Apparently, a normal "toothpaste saliva mixture" does not seem to be sufficient to achieve an efficient "hydrodynamic effect". If, however, the sonic toothbrush is combined with a continuous water supply (WST), significantly higher reductions in the plaque index value are achieved both in the areas of smooth and approximal surfaces. The WORT also showed higher reductions in the plaque index value compared to the ORT, both on the smooth and approximal surfaces, but this was not statistically significant. Movement of liquid around the bristles is not only observed for sonic toothbrushes, but also for other electric toothbrushes, which may have an additive effect on the purely mechanical action of the toothbrush [18]. Sahota et al. (1998) concluded that plaque removal depends both on direct bristle contact and on the presence of fluid [18]. They could observe that although plaque removal is mainly due to the mechanical action of the bristles, additional plaque removal occurs through turbulence; this arises when the bristles work in an aqueous environment. The results of the present study confirm this hypothesis.

A dry mouth has been observed in many elderly patients [14]. The causes of decreased salivation at old age are manifold; among them are a decrease in chewing activity, changing dietary habits, lower fluid intake or a systemic medication that reduces salivation [14]. Sufficient toothpaste-saliva mixture during the brushing process may not be formed for these patients. Therefore, these patients could benefit from a toothbrush with continuous water supply. With regard to toothbrushes with continuous water supply, it is difficult to make comparisons of literature due to the low number of studies. Sumi et al. (2003) examined the efficiency of an electric toothbrush with an oscillating motion pattern and continuous water supply as compared to a conventional electric toothbrush with oscillating motion pattern in elderly patients in terms of plaque removal in the area of smooth surfaces. They concluded that the modified toothbrush removed significantly more plaque in the area of smooth surfaces [26]. This result is comparable to those of this pilot study. In this study, higher reductions in plaque index value were observed for the modified toothbrush with oscillating motion pattern as compared to the conventional toothbrush as well.

In the approximal area, the ORT barely showed any differences in the reduction of the plaque index value compared to the WORT. Even with the WST, only a 30.14 % reduction of the plaque index value was achieved in the approximal area. These results suggest that sufficient cleaning in approximal spaces is difficult without additional hygiene tools. However, it should be noted that the index used in the present study to assess plaque in approximal areas is an index that only makes a yes/no decision on the presence of plaque in the approximal areas. The extent of plaque is therefore not taken into account. In order to assess cleaning efficiency as well as motivate the patient, a statement regarding the extent of plaque reduction would be more meaningful than just a statement regarding complete plaque removal [10]. Furthermore, in assessing the approximal cleaning performance of the toothbrushes, the possible "user errors" already mentioned above should also be taken into consideration.

In addition to the cleaning efficiency of the different toothbrushes, the subjective impression of the participants was also evaluated by means of a questionnaire. All subjects stated that they had a better "feeling in the mouth" after using the "wash toothbrushes" compared with the conventional electric toothbrushes. In choosing between the two "wash toothbrushes", over 80 % of the subjects preferred the WST over the WORT. This subjective impression is reflected in the clinical values as well.

The toothbrushes were only tested once by the participants. Many participants claimed that they needed to get used to the continuous water supply of the modified toothbrushes and that it was difficult to concentrate on the brushing process when the water supply was switched on. Moreover, in interpreting these results, it should be taken into account that not all participants were already familiar with electric toothbrushes, as 25 % of them used a manual toothbrush for their home-based oral hygiene. An influence of these aspects on the results of the reduction of the plaque index values cannot be ruled out. Hence, in future studies, an "adjustment period" should take place in advance so that the participants have time to familiarize themselves with the use of different toothbrushes. It would also be desirable to evaluate the corresponding toothbrushes over a longer time period in the context of home-based home oral hygiene.

In order to collect the indices, the plaque was visualized using a plaque disclosing solution. However, neither a demonstration nor an explanation of the plaque afflicted sites ensued for the participants. The brushing process was performed by the retirement-aged participants in an oral hygiene room, which had a sink and an unlit mirror. Moreover, the subjects were at least 50 cm away from the mirror. In this manner, the participants had no possibility to recognize the plaque-prone spots in detail on site. Therefore, the visualization of plaque could not have influenced the brushing results.

In the present pilot study, mechanical plaque removal with the various toothbrushes was combined with the use of toothpaste since the majority of the population also uses toothpaste for home-based oral hygiene. All patients used the same toothpaste with medium abrasiveness at all times. In a systematic review, it was shown that the use of toothpaste plays a rather disorderly role in supporting mechanical plaque removal. Valkenburg et al. (2016) determined that, as part of mechanical plaque removal, 49.2 % of the plaque was removed in combination with toothpaste and 50.3 % without toothpaste [28]. In this regard, an additive effect of toothpaste on plaque removal can also be neglected in the present pilot study.

5. Conclusion

Taking the limitations of this pilot study into account, it appears that an electric toothbrush equipped with a continuous water supply has a positive effect on dental plaque control in elderly subjects. Moreover, it appears that a sonic toothbrush profits from a continuous water supply to a greater extent than an electric toothbrush with an oscillating-rotating movement pattern. Further investigations should evaluate whether the application of an electric wash toothbrush can increase the "hydrodynamic effect" and whether it can thereby also reach hard-to-access niches such as exposed root surfaces or crown margins.

Conflicts of Interest:
The authors declare that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

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